Complementary feeding Habits of Golden Perch *Macquaria ambigua* (Richardson) (Percichthyidae) and Silver Perch *Bidyanus bidyanus* (Mitchell) (Teraponidae) in farm Dams

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A comparison was made of the diets and morphology of the alimentary tracts of golden perch *Macquaria ambigua* and silver perch *Bidyanus bidyanus*. Each species was grown in monoculture in farm dams and their diets compared with the available food sources using the prey-selection index C. The two species were then cultured together and the dietary overlap measured using Schoener's index. Golden perch proved to be a macrophagic carnivore, eating insects and crustaceans, whereas silver perch was an omnivore, feeding predominantly on zooplankton. The alimentary tract of golden perch is typical of a carnivore, whereas that of silver perch is adapted to an omnivorous diet, with a filtering mechanism on the gill rakers for capturing zooplankton. On the basis of their dietary habits, these two species are ideally suited for polyculture.

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INTRODUCTION

Large numbers of golden perch (*Macquaria ambigua* (Richardson 1845): Percichthyidae) and silver perch (*Bidyanus bidyanus* (Mitchell 1838): Teraponidae) are stocked annually in farm dams throughout eastern Australia, to provide fish for recreational angling and domestic consumption (Rowland *et al.*, 1983; Rowland, in press a,b). Management for fish production is minimal, since the primary purpose of the dams is for watering domestic stock. Consequently, fish stocking rates are usually low, in the region of 150-350 fish/ha, and the carrying capacity of the dams is only 200-500kg/ha (Barlow, in press). One method of increasing the production of fish in these dams is to stock two or more species with complementary feeding habits, that is, polyculture.

Little is known about the diets of golden perch and silver perch, although limited observations indicate that golden perch is a carnivore, feeding mainly on crustaceans, insect larvae and molluscs, and that silver perch is an omnivore, consuming small aquatic insects, molluscs, earthworms and plant material (Merrick and Schmida, 1984).

The aim of this study was to investigate the feeding habits of golden perch and silver perch reared in farm dams and thus ascertain if these fishes are suitable for polyculture. This was done by determining the preferred foods of the two species when grown separately, and then comparing their diets when grown together. The morphology of their alimentary tracts was also examined.

Materials and Methods

The fish used in the trials were artificially bred and reared at the Inland Fisheries Research Station, Narrandera. Those used in the monoculture trial were one year old, whereas those used in the polyculture trial were three years old. The fish were stocked in earthern dams situated in flat or gently undulating pastoral country. The dams were about 0.06ha and 2-3m deep. The dam stocked with golden perch in the monoculture trial had a dense growth of red milfoil, *Myriophyllum verrucosum*, extending 2-3m from the shore and occupying the entire perimeter of the dam. The other dams did not contain macrophytes. The food available to the fish consisted of the organisms produced naturally in the dams.

MONOCULTURE TRIAL

Twenty-eight golden perch were placed in one dam and 25 silver perch in another in January 1980, and harvested with a seine net three weeks iater. The fish were transported live to the laboratory in plastic bags containing water and an oxygen atmosphere. The total length and weight of each fish were recorded and the alimentary tract, from the oesophagus to the anus, removed and measured. Examination of the transporting medium showed that no regurgitation or defaecation occurred between the time of capture and dissection.

Macroinvertebrates in the guts were identified and counted. In addition, the percentage of zooplankton in the stomach contents of each silver perch was estimated volumetrically.

The available food sources, or potential prey species, were sampled with a 500μm dredge net. Samples collected with the dredge net provide an accurate estimate of the relative abundance of epibenthic animals in farm dams (Barlow *et al.*, 1982). To sample the dam containing milfoil the net was modified by removing the kick chain and attaching a rake to direct weed under the net (Topp, 1967). Ten samples were collected from each dam six days before the fish were sampled. The macroinvertebrates in all samples were later identified and counted. Three plankton samples were collected from the dam containing silver perch using an 100μm plankton net towed horizontally for 15m just below the surface.

The diet of the fish was compared with the available foods using the prey-selection index, C, which is statistically testable for any degree of selection at any sample size (Pearre, 1982). C is zero valued for no selection and has the limits -1 for complete selection and -1 for complete avoidance. Statistical tests were conducted using χ^2 tests (method 3 of Pearre (1982)).

POLYCULTURE TRIAL

The dam was stocked with 14 golden perch and 28 silver perch in November 1981 and harvested in April 1982. The fish were transported to the laboratory and dissected as described above. The diets were analysed by determining the percentage volume occupied by each food item in each stomach, as recommended by Wallace (1981).

In addition to determining the degree of interspecific overlap, the degrees of intraspecific overlap were also calculated to ascertain how well the diets of each species were characterized (Wallace and Ramsey, 1983). Specimens of each species were randomly divided into two sets and the dietary overlap calculated. This procedure was repeated 25 times for each species, and the means and standard deviations computed.

The degree of dietary overlap was determined using Schoener's index

$$\alpha = 1 - 0.5\left(\sum_{i=1}^{n} |p_{xi} - p_{yi}|\right)$$

where p_{xi} is the proportion of food item i in the diet of group x, p_{yi} the proportion of food item i in the diet of group y and n the number of food categories. Computed values range from 0 for no overlap to 1 for complete overlap. Although there is no statistical method for judging the reliability of overlap (Wallace and Ramsey, 1983), it is generally considered to be biologically significant when the value exceeds 0.60 (Zaret and Rand, 1971).

ALIMENTARY TRACT MORPHOLOGY

Analyses were conducted on all one year old fish from the monoculture experiment and a further 15 two year old golden perch and 20 two year old silver perch. All measurements were taken to the nearest millimetre on fresh specimens. Total length was measured, the digestive tract was then dissected out, laid on a dry enamel dish, and the lengths of the stomach and intestine-rectum measured immediately. The relationships between the gut length (oesophagus to anus) and total length were determined, and the ratios of intestine-rectum length : stomach length were calculated. The dentition and gill rakers were examined and illustrated.

RESULTS

MONOCULTURE TRIAL

The food organisms sampled from each dam, the dietary analysis and C values for golden perch and silver perch are given in Tables 1 and 2 respectively. The values of C indicate selection or avoidance of a food type, but the reality of selection or avoidance is shown only by the level of significance of C. Identification of the macroinvertebrates was usually possible to the species level, with the exception of the Notonectidae which could not be identified beyond family, and larval insects which usually could not be identified below order. The greater diversity of insects in the dam containing golden perch was probably due to the presence of macrophytes.

Golden perch consumed a wide range of macroinvertebrates. Corixid nymphs, which comprised about 50% by volume of the diet, were the major food. The most preferred, or actively selected, organisms were notonectids and the corixid *Agraptocorixa eurynome*. Three other comparatively abundant corixids were avoided, even though one, *Agraptocorixa parabiopunctata*, was similar in size to *A. eurynome* (approximate total length of adults 7mm and 9mm respectively). No zooplankton was found in the stomachs of golden perch.

The stomach contents of silver perch comprised 80% zooplankton, with the remainder being macroinvertebrates, allochthonous plant material and gravel. The stomach contents of 16 fish consisted entirely of zooplankton. There was comparatively little zooplankton in the intestines compared with the stomachs, but this is to be expected because of the rapid digestion of zooplankton. The percentage composition of zooplankton consumed by silver perch differed markedly from that collected from the dam, as shown below:

	Cladocera	Copepods	Ostracods
Consumed by silver perch	78%	22%	trace
Collected from dam	26%	74%	—

However, it is not known if these samples, collected from just below the surface of the dam, accurately represented the relative abundance of the zooplankton groups.

TABLE 1

Total number of each food type sampled from the dam (Na) and found in the diet (Nd) of golden perch (T.L. 224 ± 35mm, Wt. 188 ± 100g) reared in a monoculture trial; the prey selection index C and the level of significance for C.
N.S. not significant, ** P < 0.01, *** P < 0.001

FOOD TYPE	Na	Nd	C	Significance of C
Notonectidae	57	129	0.234	***
Corixidae				
Sigara spp.	640	24	-0.056	***
Agraptocorixa eurynome	321	345	0.317	***
Agraptocorixa parabiopunctata	157	0	-0.039	***
Micronecta annae group	3983	3	-0.246	***
Nymphs	4099	712	0.101	***
Dytiscidae				
Sternopriscus multimaculatus	543	1	-0.075	***
Megaporus howitti	41	49	0.120	***
Antiporus gilberti	42	1	-0.014	N.S.
Necterosoma wallastoni	9	0	-0.005	N.S.
Hydrophilidae				
Spercheus sp.	3	0	-0.003	N.S.
Laccobius sp.	0	1	0.011	N.S.
Unidentified sp.	0	1	0.011	N.S.
Hydracarina	274	1	-0.051	***
Hydraenidae	0	1	0.011	N.S.
Atyidae				
Paratya australiensis	3	0	-0.003	N.S.
Atheriniformes				
Gambusia affinis	2	0	-0.006	N.S.
Mollusca				
Physa sp.	12	0	-0.007	N.S.
Larval insects				
Trichoptera	35	22	0.059	***
Odonata	2	3	0.026	**
Coleoptera a	8	0	-0.004	N.S.
Coleoptera, Hydrophilidae	12	4	0.013	N.S.
Diptera, Culicidae	35	2	-0.007	N.S.
Diptera, Chironomidae	6	0	-0.002	N.S.
Ephemoptera a	18	0	-0.010	N.S.
Ephemoptera b	62	0	-0.023	**
Ephemoptera, Baetidae	205	5	-0.036	***
Lepidoptera, Pyralidae	3	1	0.001	N.S.
Plecoptera	94	57	-0.010	N.S.
TOTAL NUMBER	10666	1312		

Silver perch selectively fed on notonectids, but avoided both crayfish, *Cherax destructor* and mosquitofish, *Gambusia affinis*. Of the macroinvertebrates eaten by silver perch, 45 were found in the intestines and 15 in the stomachs. The large proportion of macroinvertebrates in the intestine possibly indicates a diel feeding pattern or perhaps different rates of passage through the stomach and intestine.

POLYCULTURE TRIAL

The intraspecific dietary overlap value for golden perch was 0.80 ± 0.06 and for

TABLE 2

Total number of each food type sampled from the dam (Na) and found in the diet (Nd) of silver perch (T.L. 205 ± 23mm, Wt. 111 ± 36g) reared in a monoculture trial; the prey-selection index C and the level of significance for C.
N.S. not significant, * $P<0.1$, ** $P<0.01$, *** $P<0.001$

FOOD TYPE	Na	Nd	C	Significance of C
Notonectidae	29	41	0.305	***
Corixidae				
Sigara sp.	0	4	0.156	*
Nymphs	0	4	0.156	*
Dytiscidae				
Antiporus gilberti	3	2	-0.027	N.S.
Larval insect	1	4	0.106	N.S.
Parastacidae				
Cherax destructor	11	0	-0.230	**
Atheriniformes				
Gambusia affinis	34	4	-0.391	***
TOTAL NUMBER	78	59		

silver perch 0.84 ± 0.04. These values indicate that the diet of each species was well characterized, even though there were comparatively few fish in the samples. Thus, it is valid to use the present data to compare the diets of these species.

The interspecific dietary overlap value was 0.23, indicating that the diets of the two species were significantly different. The major items consumed by golden perch were trichoptera larvae (63%) and crayfish (14%). In contrast, the major foods of silver perch were chironomid larvae (34%), cladocera (14%) and ostracods (10%), while trichoptera larvae formed only 7% of the diet and crayfish were absent from the silver perch stomach contents (Fig. 1).

ALIMENTARY TRACT MORPHOLOGY

The shape of the mouth and dentition of the two species are illustrated in Fig. 2. Golden perch has a large mouth, and possesses teeth on the upper and lower jaws, vomer, palatines and roof and floor of the pharynx. The teeth are numerous, tiny and stout. All teeth are set in bony plates. In contrast, silver perch has a comparatively small mouth, and possesses teeth on the upper and lower jaws and the roof and floor of the pharynx. The villiform teeth are conical and pointed, and generally aligned to point posteriorally. An exception to this is the outer band of larger teeth on the premaxillary, which point ventro-anteriorally and in some instances protrude slightly beyond the lips. The premaxillary and mandibular teeth are set in bony plates while the upper and lower pharyngeal teeth are embedded in fleshy pads.

In both species, gill rakers form an anterior and posterior series on all four gill arches. The anterior rakers on the first arch are elongated, whereas the posterior series on the first arch and all rakers on the other arches are shorter (Fig. 3). The gill rakers of golden perch are short and firm and covered with tiny tubercules which provide a rough surface. The gill rakers of silver perch are finer and adorned with rows of villiform teeth on both margins of the flat edge of the rakers facing the pharyngeal cavity (Fig. 3). The arrangement of the rakers is such that those on adjacent arches are interposed when the arches are brought together.

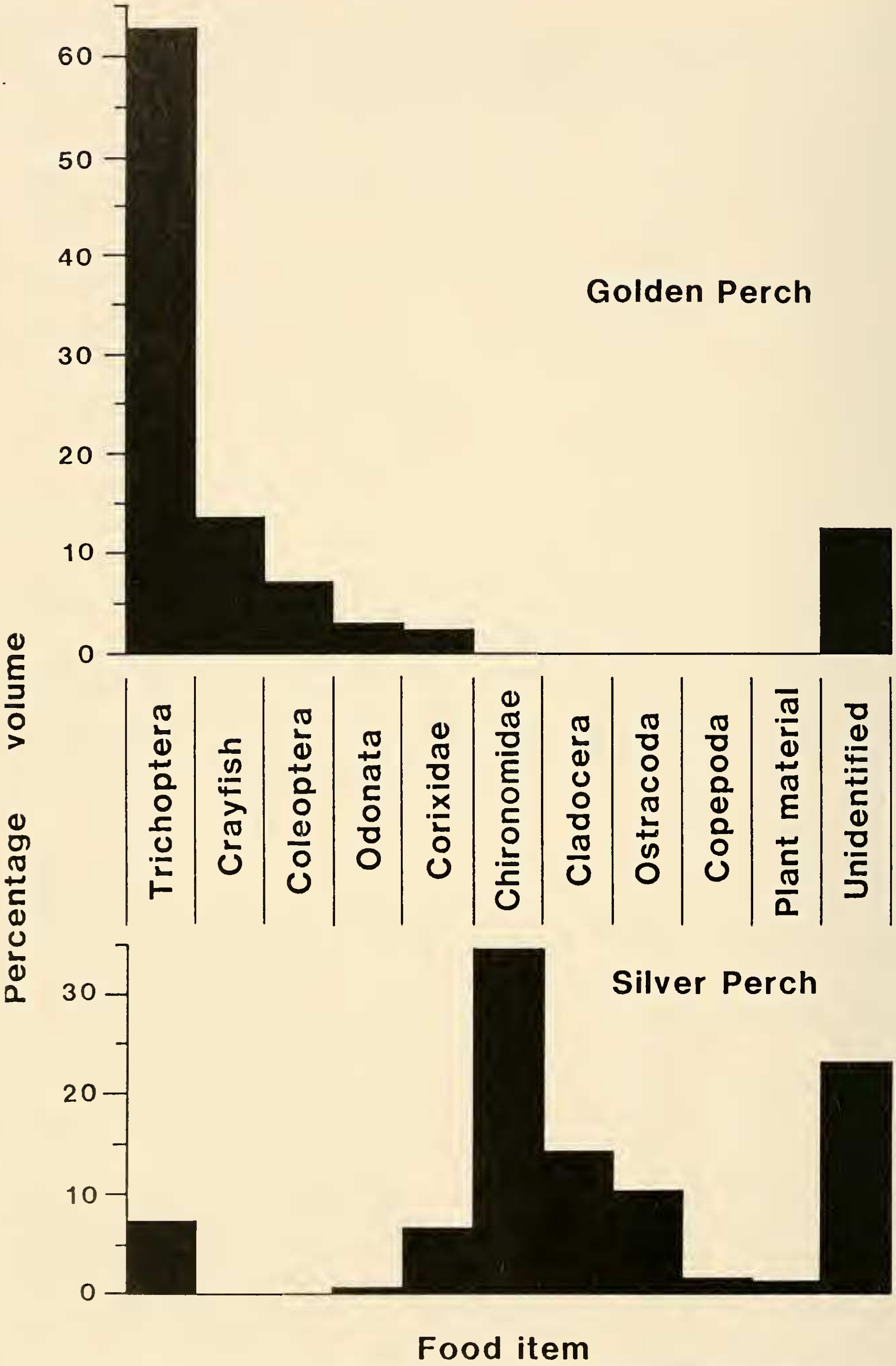

Fig. 1. Diets (average of the percentage volume of individual fish) of golden perch (T.L. 286 ± 20mm, Wt 289 ± 65g) and silver perch (T.L. 315 ± 12mm, Wt 429 ± 60g) reared in a polyculture trial.

The relationships between gut length and total length were linear for both species (Fig. 4), and were described by the following equations:

Golden perch, total length range 155-292mm,

$$GL = 0.498TL - 29.5 \quad (r=0.84, n=43, p<0.001)$$

Silver perch, total length range 175-328mm,

$$GL = 1.26TL - 106 \quad (r=0.93, n=45, p<0.001)$$

where GL = gut length and TL = total length.

The ratio of intestine-rectum length : stomach length for golden perch was 2.34 ± 0.34, and for silver perch it was 6.75 ± 1.31. That is, the alimentary tract of silver perch was longer than that of golden perch; this difference was due to the relatively longer intestine-rectum of the silver perch, rather than a difference in the size of the stomachs of the two species.

Discussion

The advantage of employing a statistically measurable prey-selection index for comparing diets and potential prey species was evident in the monoculture trial. By

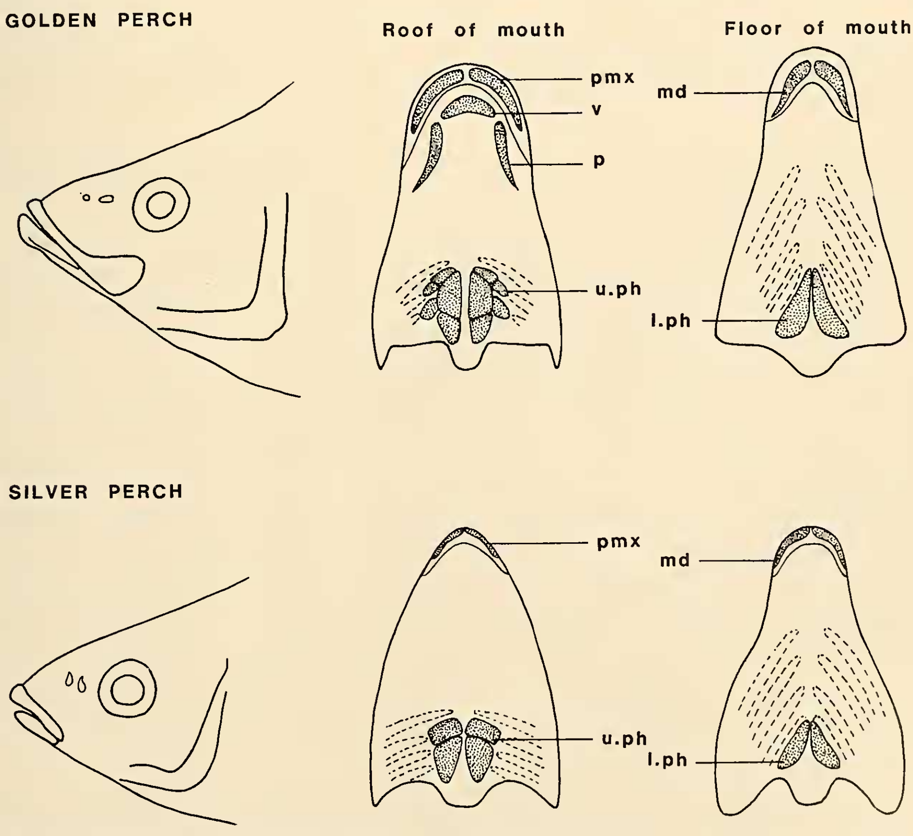

Fig. 2. Shape of the mouth and arrangement of teeth in golden perch and silver perch. (md = mandibular, pmx = premaxillary, v = vomerine, p = palatine, l.ph = lower pharyngeal, u.ph = upper pharyngeal).

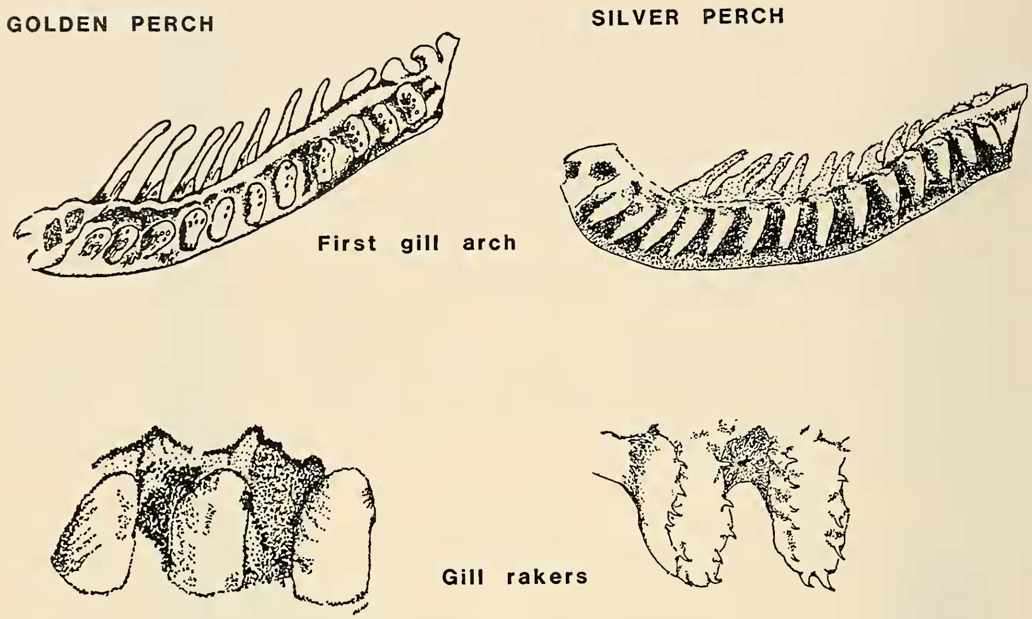

Fig. 3. The lower limb of the first gill arch of golden perch and silver perch, and magnified gill rakers showing the typical shape of the posterior rakers on the first gill arch and the anterior and posterior rakers on the second, third and fourth arches.

using C it was possible to determine which prey species were being significantly selected or avoided by the fish. Furthermore, realistic values of C could be computed even when a particular food type was absent in either the diet or the environment.

Preference ratings, however, apply only at the time of sampling; the most preferred species tend to be depleted first and the remaining species affected more or less severely according to their preference ranking and the intensity and duration of cropping (Petrides, 1975). One possible example of depletion of preferred species is the notonectids, which were actively selected by both golden perch and silver perch in the monoculture trial. However, notonectids were absent from the diets of both species in the polyculture trial, and thus presumably absent from the dam, even though notonectids are the numerically dominant insect group in farm dams in the study area (Barlow and Bock, 1981).

In the monoculture trial, golden perch fed on a wide variety of insects and the silver perch fed predominantly on zooplankton. Strict comparison of the diets was not possible because of the different available food sources. However, these apparent dietary differences were real, as indicated in the polyculture trial, in which golden perch fed mainly on trichoptera larvae and crayfish, whereas silver perch ate zooplankton and chironomid larvae. The diet of golden perch in this study agrees with published information, but the diet of silver perch indicates greater consumption of zooplankton than previous observations on the stomach contents of wild fish had indicated (Merrick and Schmida, 1984).

The morphology of the alimentary tracts also suggests that the diets of the two species are different. The large mouth of golden perch is obviously adapted for taking large prey. The numerous, tiny teeth set in bony plates, together with the stout, hard gill rakers, would aid crushing of the prey. The short intestine is also typical of a carnivore

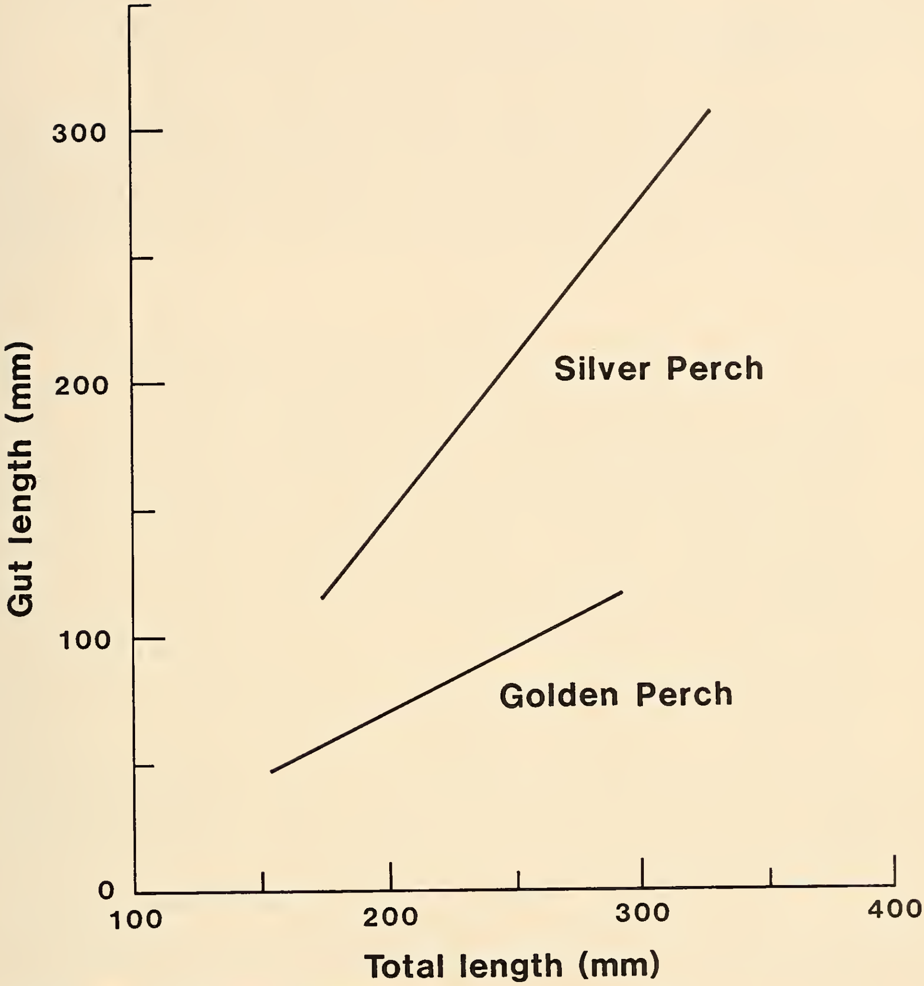

Fig. 4. Regression of gut length on total length for golden perch and silver perch.

(Das and Moitra, 1956). In contrast, silver perch has a small, terminal mouth with premaxillary teeth which are apparently capable of rasping aufwuchs from solid substrates. Aufwuchs was not present in any of the dams in this study, but periphyton has often been observed in the gut contents of silver perch from other waters (Barlow, unpublished data). Of particular interest are the villiform teeth on the gill rakers of the silver perch. These teeth form a very effective sieving device when the gill arches are brought together. Presumably, this is the mechanism silver perch uses to capture zooplankton. The comparatively long intestine of silver perch is also indicative of an omnivorous diet (Das and Moitra, 1956).

In conclusion, golden perch can be classified as a macrophagic carnivore eating insects and crustaceans, whereas silver perch is an omnivore eating mainly zooplankton, insects and aufwuchs if available. Such dietary differences indicate that these species are well-suited for rearing together in polyculture, at least in unmanaged farm dams. Although both species have many of the biological attributes necessary for successful aquaculture (Barlow, in press), research on production levels attainable in intensively managed ponds is necessary before any determination can be made regarding the economic feasibility of farming these fishes.

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